

Incident Management and Network Performance

Koorey, G., McMillan, S. and Nicholson, A.

Department of Civil and Natural Resources Engineering

University of Canterbury, Christchurch, New Zealand

Abstract

This paper describes an investigation into the scope for reducing trip time variability associated with incidents (e.g. accidents), through better incident management. The investigation involved using micro-simulation (S-Paramics) to model incident detection and response in a part of the Auckland (New Zealand) network, which includes a motorway and adjacent parallel arterial roads. The effect of blockages on the motorway or an adjacent arterial road, with and without mitigation (e.g. modifying the SCATS arterial road signal coordination plan, using variable message signing and allowing motorway traffic to use the hard-shoulder), were assessed. It was found that the reductions in the variability of trip times, as a result of implementing mitigation options, were much larger than the reductions in mean trip times.

1. Introduction

The economies in developed countries depend heavily on their transport systems, and that dependence has increased with the adoption of 'just-in-time' production methods, the success of which depends upon predictable trip times. This is especially true for freight movements, as evidenced by programmes such as the European Commission's Marco Polo programme, aimed at easing road congestion, thereby improving the efficiency and reliability of freight transport.

Concern about the travel time variability has been growing for some time, with a study for the UK Department of Transport (SACTRA, 1999) concluding that ignoring the effect of travel time variability led to the economic benefits of trunk road projects being under-estimated by between 5% and 50%. A subsequent UK study (Eddington, 2006) also stressed the importance of accounting for the reliability of travel time.

Traffic congestion is commonly divided into 'recurring' congestion, which occurs when there is regularly not enough capacity in the transportation system to meet the demand (e.g. during "peak-hour" periods of the day), and 'non-recurring' congestion, which occurs when there is a temporary and 'unexpected' reduction in capacity due to incidents (e.g. crashes, vehicle break-downs). Both types of congestion are important, with incidents being estimated to be responsible for about half of the congestion on US freeways (US DoT, 2000; Schrank and Lomax, 2009).

It seems likely that variability associated with recurring congestion will be allowed for in trip planning, with the occasional instances of unexpectedly high delay being largely associated with non-recurring congestion. It therefore seems likely that reducing non-recurring congestion will have a greater effect on the perception of reliability than reducing recurrent congestion.

Successful management of incidents on road networks involves both efficient detection of incidents (including identifying their location and nature, preferably by automated means) and identifying suitable treatment options, both in terms of removing or fixing the cause of the incident and managing vehicle flows during and after the incident.

Williams and Guin (2007) reviewed the various algorithms, devised since the 1970s (e.g. Payne 1975), for detecting incidents on traffic networks. While early algorithms were largely based on simple speed or occupancy comparisons and classical traffic flow theory, more recently complex techniques have been tried such as neural networks (e.g. Srinivasan et al 2004), fuzzy logic (e.g. Yaguang and Anke 2006) and wavelet transformations (e.g. Samant and Adeli 2000). Williams and Guin also report that a survey of 32 traffic management centres across the USA revealed a lot of concern with the performance of existing automatic incident detection algorithms, with 81% stating that even if reliable and accurate AID algorithms were available in the future, they would continue to employ other methods of incident detection (e.g. mobile

phone calls or operator visual detection).

Incidents are commonly of relatively short duration. While equilibrium methods can be used for modelling long-duration road closures (Dalziel and Nicholson, 2001), it has been shown that microsimulation is much more appropriate for short-duration closures (Berdica et al., 2003). There have subsequently been many studies that have used simulation to investigate the effect of short-term incidents. For instance, Hadi et al. (2013) used macroscopic and microscopic simulation modelling (FREEVAL and CORSIM respectively) to estimate the delays of previous observed incidents.

Kamga et al. (2011) looked at how network performance is affected during an incident, by simulating incidents in a dynamic traffic assignment model. A case study was performed on part of the greater Chicago network, allowing for alternative routes for origin-destination pairs. A base case scenario was generated to depict operational characteristics of the network under normal traffic flow conditions. Then, an incident was simulated for two scenarios:

- firstly, where all drivers were assumed to have no information on the incident, with all drivers being assumed to follow their current (or 'no incident') paths;
- secondly, where all drivers are assumed to have perfect information of the incident conditions, with traffic being reassigned to the network using a dynamic user equilibrium method.

Nicholson et al. (2003) also proposed considering the cases of zero and perfect information, to get upper and lower bound estimates of the impact of disruption. In practice, a real-world scenario will be somewhere between these two extremes, depending on the level of traveller information available to motorists and the propensity of motorists to ignore such information.

The results from Kamga et al. (2011) confirmed that an effective traveller information system has the potential to ease the impacts of incident conditions network wide. However the results also suggested that incidents have a different impact on different origin-destination pairs, with the use of traveller information to help reassign traffic giving an advantage to motorists travelling between some origin-destination pairs and a disadvantage to motorists travelling between other origin-destination pairs.

The focus of the study reported here is identifying effective and efficient treatments. Treatment options can be considered to fall into two categories, advanced traffic management systems (ATMS) and advanced traveller information systems (ATIS). ATMS options include:

- dynamic traffic signal control, with signal timings being adjusted as traffic flow patterns change;
- traffic signal pre-emption for public transport or emergency vehicles;
- dynamically varying speed limits;
- lane use control (e.g. tidal flow systems, temporary shoulder use);
- ramp metering to limit access to motorways;

ATIS options include:

- dissemination of real-time traffic information via traffic reports on the radio and internet, or variable message signs;
- in-vehicle navigation systems.

Three of the above options (dynamic signal control, temporary shoulder use, variable message signs) were investigated in the study reported here.

The effectiveness of variable message signs (VMS) can vary widely, with Hidas (2001) reporting that traffic diversion rates for VMS routing can range from 5% to 80%, with the most important factor affecting the decision whether to divert being network familiarity. For example, motorists with a good knowledge of the network might ignore the VMS-suggested diversion and select their own perceived optimal route, with motorists might be unwilling to change routes during an incident if they are unsure of the reliability of alternate routes.

The study reported here was undertaken in two stages. The first involved an exploratory study to assess the feasibility of modelling traffic in a network, containing a motorway and an adjacent parallel arterial with a dynamic traffic signal control system (SCATS), to assess the ability of SCATS to detect and respond to traffic flow changes arising from closure of motorway lanes (Koorey et al., 2008). The second stage involved extending the modelling, in terms of the area being modelled, the incident scenarios tested and the range of treatment options (Koorey et al., 2014).

2. First Stage Study

The SCATS dynamic traffic signal control system is used in every major city in New Zealand (NZ) to adjust signal timings at signalised intersections, to optimise the performance of the urban network or part of that network, and is considered an effective method for handling the typical gradual changes in traffic flows within a network over time. There is considerable interest in identifying how well it can detect and respond

to major traffic incident (e.g. accident or blockage) or abnormal traffic demand (e.g. travel to/from a major sports or cultural event).

SCATS is traditionally based around stop-line detectors, making it difficult to detect the presence of large queues upstream of intersections. At the time of the first stage study, SCATS measured the degree of saturation based on detector occupancy, rather than the actual flow rate, and this did not distinguish between many vehicles passing over the detectors at a 'high' speed during a period (i.e. uncongested traffic flow) and a few vehicles passing over the detectors at a 'low' speed during a period (i.e. congested traffic flow); as both conditions give a high occupancy. These features of SCATS limited its ability to detect and respond to congestion associated with traffic incidents.

Microsimulation had been used on several previous occasions to model traffic incidents. One study (Gale and Spiers, 2001) investigated the use of microsimulation modelling to determine the best choice of management plan following an incident on Birmingham's motorway network. This study involved modelling a fixed-time (non-dynamic) signal control system. Similar applications of microsimulation to incident modelling with non-dynamic signal control had also been investigated in Australia (e.g. Stazic et al., 2004; Dia and Cottman, 2004). Microsimulation of a SCATS-controlled traffic signal network, to assess its performance, had been studied (Millar et al., 2004; Zhang and Taylor, 2006), but there had been little (if any) use of microsimulation for investigating the performance of SCATS control after an incident.

By default, fixed signal phase times are specified in most microsimulation models, and it is common practice to model SCATS-controlled intersections in microsimulation models by using the average timings from SCATS. As noted by Zhang and Taylor (2006), it is difficult to effectively model SCATS-controlled signals using fixed-time signal plans, as fixed-time signals are unable to react to the change in demand resulting from incidents. As noted by Lowrie (2006), SCATS can be 'interfaced' with microsimulation models (including Q-Paramics, S-Paramics, AIMSUN and VISSIM), to enable microsimulation models to simulate variable signal phase times. For this study, SCATS was interfaced with S-Paramics, using the "baseplus FUSE" software (Transit NZ, 2006).

2.1. First Stage Study Method

An S-Paramics model of a small portion of Auckland (see Figure 1) was calibrated and used for the first stage study. The study area included a portion of Auckland's Northern Motorway and a parallel route (along Wairau and Taharoto Roads) through the adjacent urban arterial network. The network model is shown in Figure 2. The Auckland Harbour Bridge lies just to the south of the study area, with the CBD just south of the bridge. The Northern Motorway is part of State Highway 1 (SH 1), and is not only a key part of Auckland's traffic network, but also the main national north/south route.

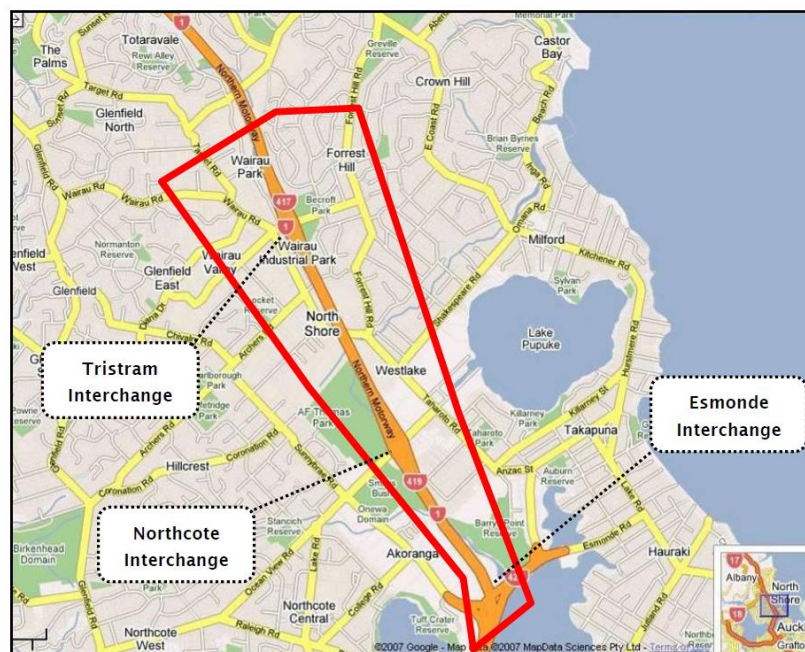


Fig. 1: Study Area for First Stage

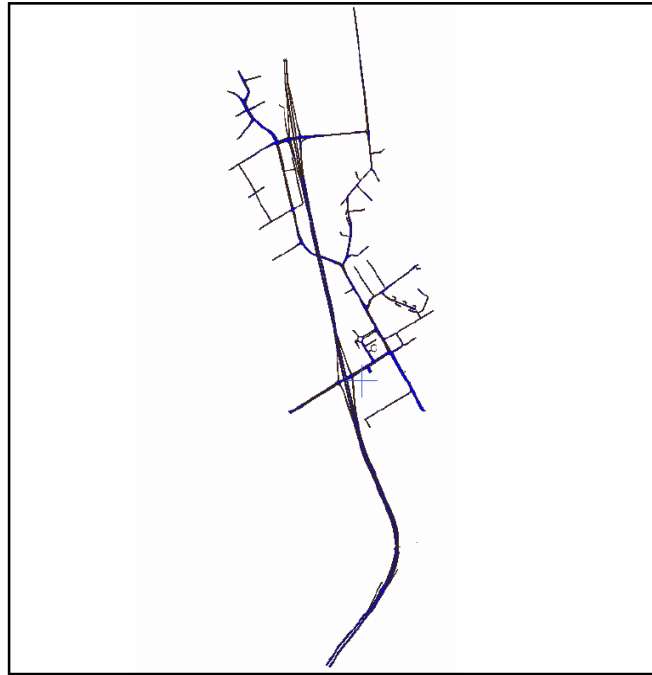


Fig. 2: Network Model for First Stage

Three different scenarios were modelled:

- base scenario with no incident;
- an incident on the motorway with traffic diverting to the arterial route, with SCATS left to respond as per normal (incident with original SCATS);
- an incident on the motorway with traffic diverting to the arterial route, with changes to SCATS to give priority along the adjacent arterial route, to assist diverting traffic (incident with modified SCATS).

The incident involved closure of both the kerb-side and centre lanes of the northbound three-lane carriageway of the Auckland Northern Motorway, between the Northcote and Tristram interchanges. Both lanes were closed from 3.30 pm, with the centre lane remaining closed until 3.45 pm and the kerb-side lane remaining closed until 4.00 pm. The consequence of such a closure is that northbound traffic on the motorway might leave the motorway at the southern end of the section of motorway (i.e. the Northcote interchange) and divert to the adjacent arterial, before re-joining the motorway at the Tristram interchange (see Figure 3), while northbound traffic on the adjacent arterial might remain on the arterial and join the motorway at the Tristram interchange instead of the motorway Northcote interchange (see Figure 4).



Fig. 3: Northcote Diversion

It was anticipated that the effect of an incident would depend upon the time of its occurrence. For instance, an incident in a period with low traffic flows (e.g. late at night) may have little effect on travellers, with little benefit accruing from any incident management. Conversely, for a network already operating at or near capacity, it may be very difficult (if not impossible) to achieve any meaningful improvement in network

performance if an incident occurs. For this study the shoulder of the peak period was chosen, as an incident would affect a large number of travellers, but there would be some spare capacity on the network, so that the benefits of incident management might be substantial.

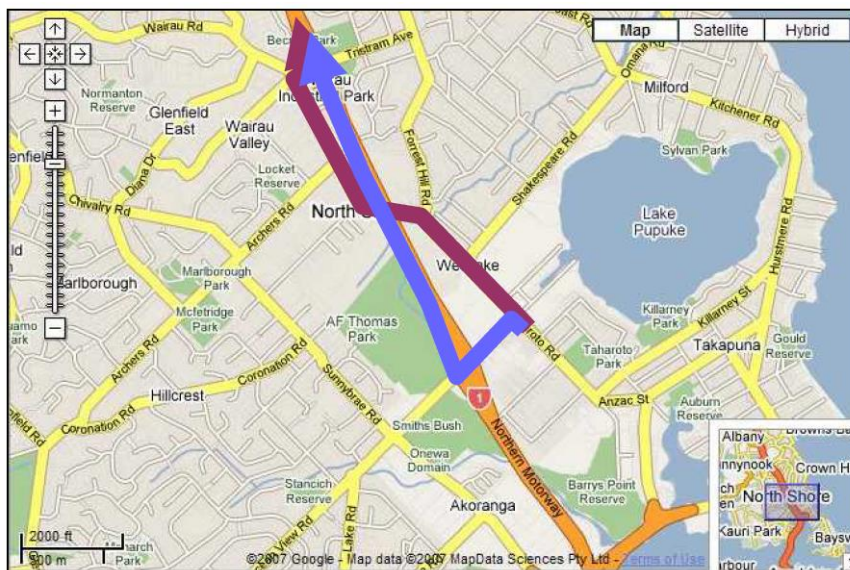


Fig. 4: Taharoto Diversion

2.2. First Stage Study Results

For the incident scenario without modification of SCATS, the mean travel time on the motorway (from the Northcote interchange to the Tristram interchange) was 35% greater than for the base case, but with modification of SCATS, the increase was somewhat less (29%). For the incident scenario without modification of SCATS, the mean travel time on the Northcote diversion route (from the Northcote interchange to the Tristram interchange) was 81% greater than for the base case, but with modification of SCATS, the increase was much less (68%). For the incident scenario without modification of SCATS, the mean travel time on the Taharoto diversion route (from Taharoto Road to the Tristram interchange) was 41% greater than for the base case, but with modification of SCATS, the increase was a little less (39%).

The results showed that an improvement in travel time for traffic diverted due to incidents could be achieved with modifications to SCATS. The modifications made were minor and similar to the modifications a SCATS operator at a traffic control centre would make when such an incident was detected on the motorway. The changes were made only for the duration of the incident after which SCATS reverted to the original settings.

The results also showed that the benefits of incident management plans may be limited to some particular journey paths. For example, travellers already on the motorway generally did not benefit by diverting onto the local road network to avoid the congestion due to the incident; this is likely to be due to the short-term nature of the incident and the fact that the northbound carriageway of the motorway was not completely blocked. However, travellers approaching the motorway to enter it could benefit by being diverted further north before entering the motorway. The value of the first stage study was limited, as the size of the study area and model network allowed for only two paths.

3. Second Stage Study

The study area was expanded by combining two S-Paramics models, the “Wairau Road model” (used in Stage 1) and the “Takapuna model”, which had been created for the adjoining area, to help assess a development project. The expanded study area is shown in Figure 5, and the network model is shown in Figure 6.

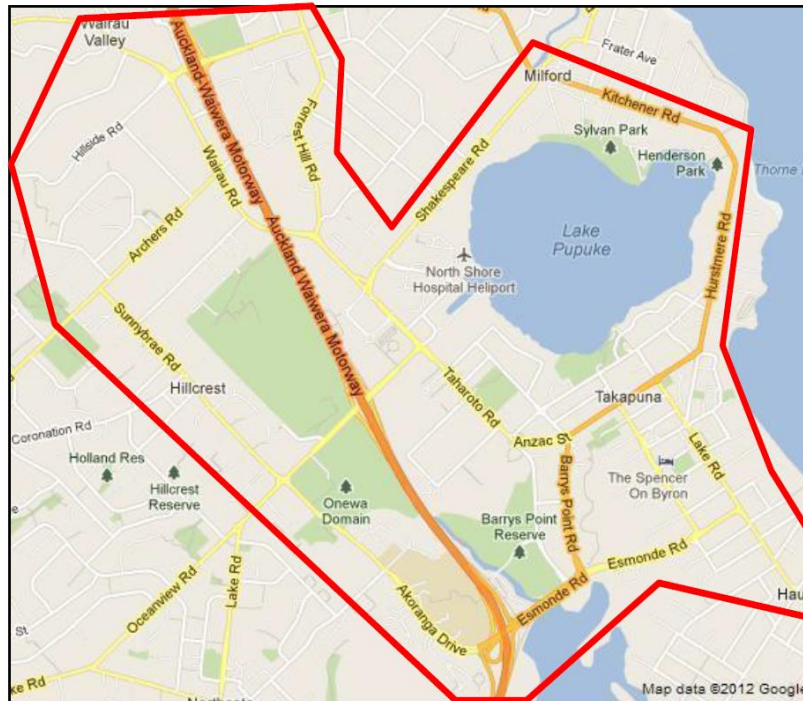


Fig. 5: Study Area for Second Stage

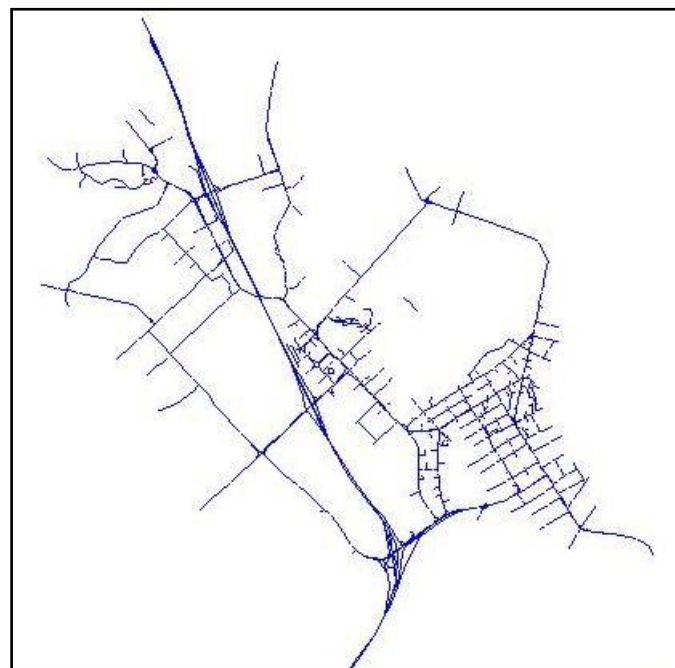


Fig. 6: Network Model for Second Stage

3.1. Second Stage Study Method

Combining the two S-Paramics models involved adjusting both models, to ensure consistency across the whole network. The size and complexity of the combined base model (no incident) meant that calibration, done for the period from 3.15 pm to 7.30 pm, was challenging. While the model calibration did not meet all the calibration criteria specified by the NZ Transport Agency (2010), the calibration was considered good enough to have a good level of confidence in the use of the model for the testing the ability of SCATS to respond to incidents on specific routes. For instance, a regression analysis of modelled versus observed flows for all individual links in the network model (Figure 6) gave a coefficient of determination equal to 0.96, which is substantially greater than the specified minimum of 0.85 (NZ Transport Agency, 2010). The Root-Mean-Square Error for entire network was 22%, which is substantially less than the specified maximum of 30% (NZ Transport Agency, 2010).

The size and complexity of the model resulted in the running time, with interfacing of SCATS and S-Paramics to facilitate simulation of variable signal phase times, exceeding real time.

Incident data were collected for some actual incidents that occurred on Auckland's motorway network between 2007-2010 and appeared relevant to this study. The following data were sought for the incidents:

- incident reports, with details of location, and start and finish times of incidents, along with details of the traffic management actions and the time when the incident was cleared;
- motorway vehicle count data for the period from the start of the incident to the clearance time;
- SCATS vehicle count data for each lane (at the stop-line) of signalised intersections for the same period;
- SCATS signal timings (cycle and phase split times) for the same period.

A complete set of data was available for only one incident.

This incident occurred on the southbound carriageway of the motorway, between the off-ramp and on-ramp at the Northcote interchange, and involved complete closure of the carriageway. The incident occurred shortly before 5.45 pm (i.e. during the pm peak), but in the 'off-peak direction'. The period of closure was from 5.50 pm to 7.33 pm, by which time the traffic queue had been cleared. Vehicles were diverted off the motorway at the Northcote interchange southbound off-ramp and allowed to proceed directly through the interchange to rejoin the motorway via the Northcote interchange southbound on-ramp, with the traffic signal plan at the Northcote interchange signalised intersection being 'locked' (i.e. cycle and phase times were fixed) from 6.00 pm to 7.33 pm. Variable message signs (VMS) also directed traffic to exit at the preceding Tristram interchange southbound off-ramp.

Two hypothetical incidents, one on the motorway and one on the arterial road network, were modelled. The motorway incident was located in the southbound carriageway of the motorway, just south of the Northcote interchange off-ramp (in a similar location to the actual incident described above), while the arterial road incident was located immediately east of the motorway on the westbound lanes of Northcote Rd (i.e. approaching the motorway interchange), as shown in Figure 7.

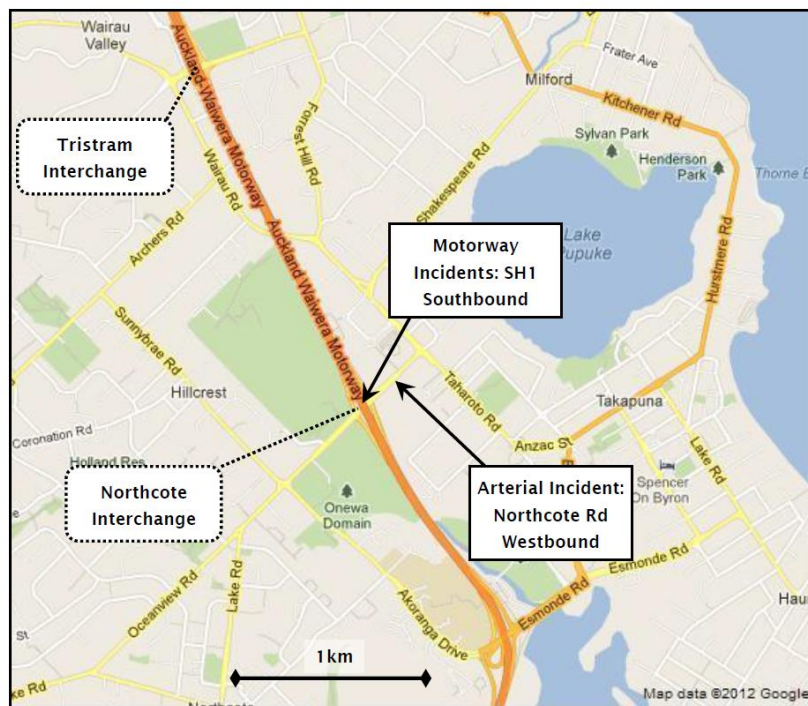


Fig. 7: Modelled Incidents for Second Stage

The modelled motorway incident involved a partial reduction in capacity, with reductions in traffic speeds in the three traffic lanes; the speeds were reduced to 50 km/h, 60 km/h and 70 km/h in the left (or kerbside) lane, the middle lane and right (or median) lane, respectively. It should be noted that the shoulder adjacent to the left lane is not normally used by traffic. The modelled incident started at 4.00pm (i.e. in the 'shoulder' of the peak period) and lasted for 15 minutes.

The modelled arterial road incident involved the first (or kerbside) lane being closed, with the speeds in the second (or median) lane being reduced to 30km/h. The incident was again started at 4.00pm and lasted for 15 minutes (i.e. during the shoulder of the peak period).

The relatively short duration of the incidents allowed the model to determine the time for the network to recover following the incidents.

For the modelled motorway incident, additional capacity was provided by simulating allowing traffic to use the motorway shoulder as an additional lane. The physical attributes of the shoulder (particularly its

constrained width) meant that its capacity is less than the capacity of a normal traffic lane, so the treatment did not fully compensate for the reduction in the capacity of the three normal lanes. In addition, VMS was used to advise southbound motorists to leave the motorway at the Tristram interchange.

For the arterial incident, the use of SCATS 'action lists', which involved modifying signal cycle times, phase green times and signal off-sets (to facilitate better progression along the arterials roads parallel to the motorway), was simulated. The aim of the 'action lists' was to produce a traffic signal scheme that was optimised for arterial road traffic travelling parallel to the motorway rather than across it.

Since the first stage study, the SCATS software was upgraded to incorporate an 'Unusual Congestion Monitor' tool (RTA, 2006), which can be configured to detect when flow over detectors is not what is expected. SCATS now considers a lane to be unusually congested if the degree of saturation is high and the flow over the detector is much lower than would be expected. SCATS assumes that unusual congestion is due to downstream queues blocking back, and monitors how many minutes a lane is unusually congested. Thresholds for the duration of unusual congestion are set in the unusual congestion monitor and if those thresholds are exceeded, the intersection affected will appear in the Unusual Congestion Monitor, with the duration of unusual congestion being indicated. In setting the threshold, there is a trade-off between how quickly an incident can be detected and how long the congestion has to exist before being considered 'unusual'. For example, setting a short threshold duration could result in relatively minor perturbations in traffic triggering an 'unusual congestion' report.

SCATS now has in-built variation routines that can be used to modify the signal operation at an intersection (e.g. changing the cycle, split or linking plan), to accommodate the congestion (Luk & Green, 2010) studied whether the Variation Routine 83 function in SCATS can balance traffic flow or density at the intersection, route or network level. The VR83 function in SCATS uses two conditions to determine when to cap the degree of saturation (DS) in SCATS. DS (a measure of traffic flow density measured at the stopline, representing the level of congestion) is a key parameter in allocating green time to a movement – the higher the value of DS, the more green time will be allocated to that movement. VR83 also looks at the ratio of the maximum possible throughput volume divided by the observed throughput volume. The VR83 function allows SCATS to redistribute green time when it cannot be efficiently utilised by a movement due to downstream congestion blocking progression of that movement.

3.2. Second Stage Study Results

For the actual incident, located on the southbound carriageway of the motorway between the off-ramp and on-ramp at the Northcote interchange, analysis of traffic count data for the off-ramp (just upstream from the incident) revealed a much higher flow during the period of the incident than typically occurs when there is no incident (see Figure 8). Southbound motorists on the motorway at the Northcote interchange had no real alternative, given that the carriageway was completely blocked just beyond the off-ramp. Analysis of traffic count data for the southbound off-ramp at the Tristram interchange (the interchange preceding the Northcote interchange) also revealed a much higher flow than typically occurs when there is no incident, especially during the latter part of the incident period of the incident (see Figure 8).

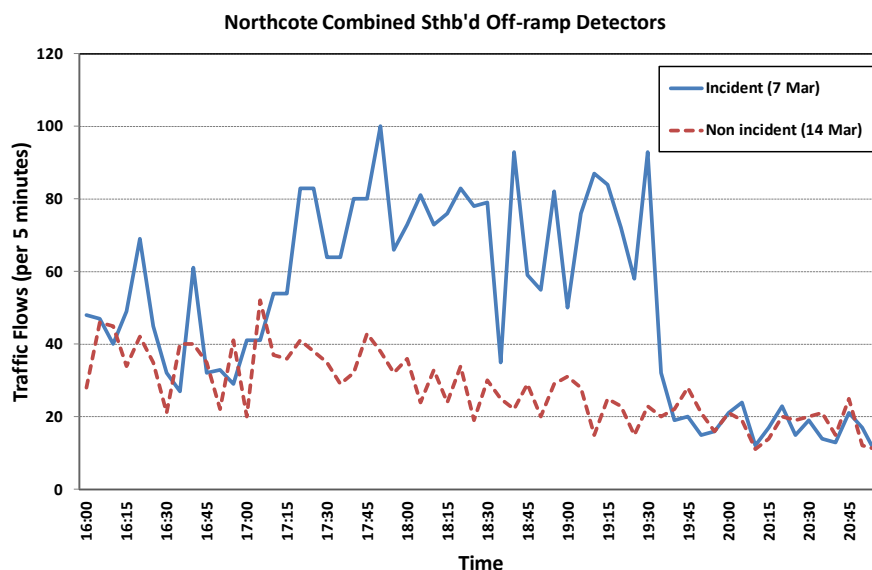


Fig. 8: Northcote Southbound Off-Ramp Flows With and Without Incident

Diversion rates of at least 30% to upstream off-ramps were noted when appropriate messages were communicated via VMS. This indicates that the use of VMS to encourage motorists to leave the motorway at the Tristram interchange was reasonably effective, as the motorists did have the option of remaining on the motorway until they reached the Northcote off-ramp.

It can be seen from Figures 8 and 9 that traffic started diverting at the Tristram southbound off-ramp about 0.5 hours after the blockage occurred at the Northcote interchange. This suggests a lag of about 0.5 hours in the effects of the blockage reaching Tristram. Given that the two interchanges are about 2.0 km apart, this suggests a queue progression rate of about 4 km/h. Alternatively it may simply reflect when the VMS display at Tristram started to influence drivers to divert early.

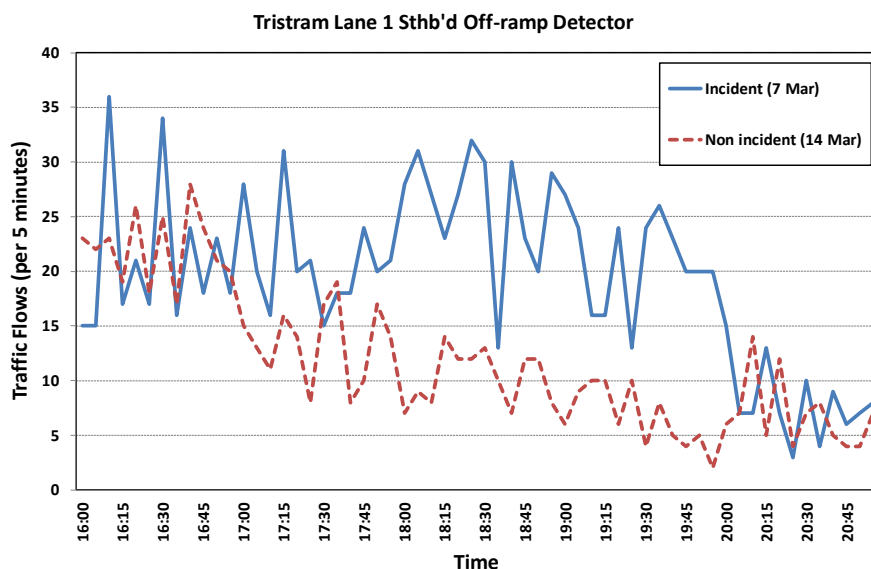


Fig. 9: Tristram Southbound Off-Ramp Flow With and Without Incident

Table 1 summarises the key results obtained from simulating the hypothetical motorway incident described above, in the absence of treatment (“Incident”) and with treatment (i.e. allowing traffic to use the shoulder as a traffic lane and implementing VMS to divert southbound traffic at the Tristram interchange. It should be noted that five model simulations were run (with different random seeds) to assess the level of variation in network performance, for both the hypothetical motorway and arterial incidents, both without and with implementation of treatment to mitigate the effects of the incidents.

Table 1: Effect of Simulated Motorway Incident on Network, Without and With Treatment

Scenario	Total Number Vehicles Modelled	Mean Travel Time (s)	Range of Travel Times and {standard deviation} (s)	Total Distance Travelled (km)	Total Network Travel Time (hrs)	Mean Travel Speed (km/h)
Incident	75,268	610	461 – 750 {126}	293,073	12,621	23.9
Treatment	79,173	487	453 – 512 {25}	319,217	10,706	29.9

It should be noted that the average numbers of vehicles modelled differ between the two scenarios. This reflects the fact that, in the base (or ‘incident’) case, not all of the traffic demand could be loaded onto the network, due to the high level of congestion. Nevertheless, the treatment was clearly successful in dramatically improving the average travel times for traffic, and increasing the corresponding mean travel speeds. The mitigation was estimated to produce a 25% increase in average speed across the entire network and a 9% increase in the average trip distance, giving a 20% reduction in the trip times. These results are even more significant considering that many trips in the wider modelled network were probably

relatively unaffected by the incident, and that in the ‘Treatment’ scenario the number of vehicles loaded onto the network was higher.

Arguably of more significance was the very large reduction in the variability of average travel times, with the standard deviation being reduced by about 80% as a result of the treatment.

Table 2 summarises the key results from the models simulating a kerb-lane closure on an arterial road near the motorway (‘Incident’) and the effects of implementing a revised SCATS action plan to alleviate this (‘Treatment’).

Table 2: Effect of Simulated Arterial Road Incident on Network, Without and With Treatment

Scenario	Total Number Vehicles Modelled	Mean Travel Time (s)	Range of Travel Times and { <i>standard deviation</i> } (s)	Total Distance Travelled (km)	Total Network Travel Time (hrs)	Mean Travel Speed (km/h)
Incident	78,559	499	430 – 593 {71}	314,401	10,871	29.4
Treatment	78,745	490	459 – 556 {39}	316,371	10,706	29.7

It can be seen that for this incident, the improvement in average travel times and mean speeds associated with the treatment is much less (between 1% and 2%). However, again the variability of average travel times is reduced substantially (by about 45%).

As noted by Kamga et al. (2011), average network data may mask significant greater changes (for better or worse) for particular paths; indeed, there may be some parts of the modelled network largely unaffected by the changes near the incident location. This was investigated, via an analysis of travel times and speeds for the five diversion paths shown in Figure 10. It should be noted that the paths include only sections of road which have a substantial movement function (i.e. motorway, major and minor arterials).

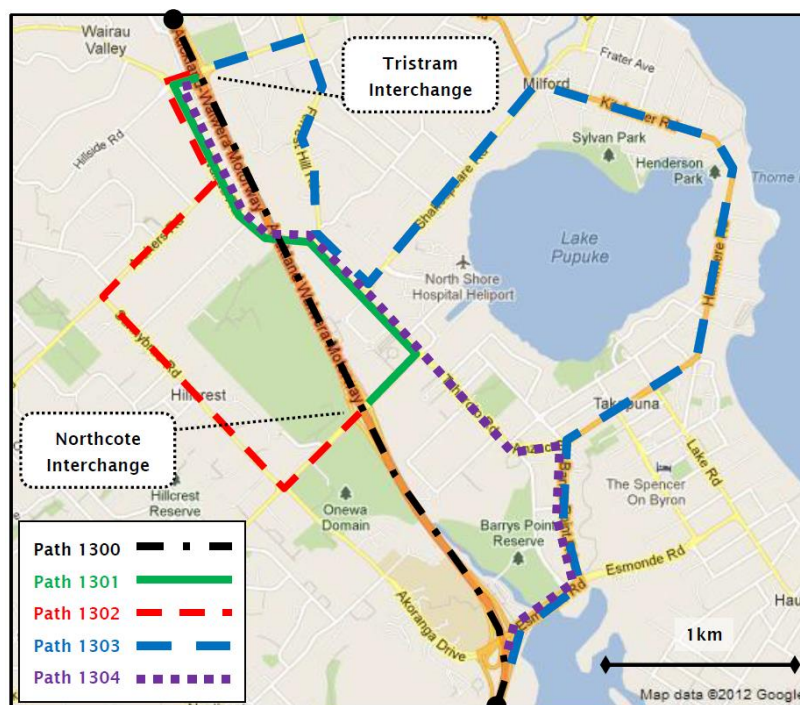


Fig. 10: Alternative Diversion Paths

Table 3 shows the mean times and speeds, without and with treatment to mitigate the effect of the motorway incident. It can be seen that the treatment generally resulted in a larger travel time reduction on the arterial routes (paths 1301, 1303, 1304) than on the motorway (path 1300).

Table 3: Effect of Simulated Motorway Incident on Particular Paths, Without and With Treatment

Path	Mean Path Length (m)	Incident		Treatment		Travel Time Reduction (%)
		Mean Journey Duration (s)	Mean Travel Speed (km/h)	Mean Journey Duration (s)	Mean Travel Speed (km/h)	
Path 1300	6484	303	77.0	295	79.1	2.6%
Path 1301	7107	656	39.0	620	41.3	5.5%
Path 1302	8118	676	43.2	665	44.0	1.7%
Path 1303	11187	1306	30.8	1219	33.0	6.7%
Path 1304	7239	818	31.9	768	33.9	6.1%

Table 4 shows the mean times and speeds, without and with treatment (changes to SCATS plans) to mitigate the effect of the arterial incident. It can be seen that the treatment generally resulted in a much larger travel time reduction on the arterial route nearest to the motorway (path 1301) than on the motorway (path 1300). It can also be seen that the treatment resulted in an increase in the travel time on some arterial paths (paths 1303 and 1304).

Table 4: Effect of Simulated Arterial Road Incident on Particular Paths, Without and With Treatment

Paths	Mean Path Length (m)	Incident		Treatment		Travel Time Reduction (%)
		Mean Journey Duration (s)	Mean Travel Speed (km/h)	Mean Journey Duration (s)	Mean Travel Speed (km/h)	
Path 1300	6484	296	78.8	291	80.1	1.7%
Path 1301	7107	663	38.6	583	43.9	12.1%
Path 1302	8118	664	44.0	643	45.5	3.2%
Path 1303	11187	1208	33.3	1219	33.0	-0.9%
Path 1304	7239	751	34.7	771	33.8	-2.7%

4. Discussion and Conclusion

The study results show that VMS displays played a substantial role in dealing with the hypothetical motorway incident, by diverting motorists off the motorway. However, the analysis of off-ramp flows during an actual incident suggests that some motorists do not divert until they see queues ahead and get validation of the message that the VMS displays were communicating.

The results indicate that allowing motorists to use the shoulder lane, which is not available for use in normal conditions, is a promising technique that can provide quite substantial performance gains when the capacity of the traffic lanes is temporarily reduced during an incident.

Implementing changes to SCATS signal plans on arterial roads (e.g. to prioritise alternative diversion routes) are a useful supplementary action for dealing with incidents on motorways, and dealing with incidents on the arterial roads.

SCATS has a range of tools that can assist with both the detection and treatment of incidents on road networks. This study involved assessing the effectiveness of 'action plans' only. While the average time savings may be small, the reduction in the variability of travel times is likely to be distinctly greater.

Acknowledgements

The research described in this paper was funded by the NZ Transport Agency and the University of Canterbury.

References

- Berdica, K., Andjic, Z., Nicholson, A.J. (2003). Simulating Road Traffic Interruptions: Does it Matter What Model we Use? In Bell, M.G.H. & Iida, Y. (ed.), *The Network Reliability of Transport*, Elsevier Science, Oxford, UK, pp.353-368.
- Dalziell, E.P. and Nicholson, A.J. (2001). Impact of Natural Hazards on a Road Network: A Risk Assessment Case Study. *American Society of Civil Engineers Journal of Transportation Engineering*, 127(2): 159-166.
- Dia, H., and Cottman, N. (2004). Evaluation of incident management benefits using traffic simulation. *Proceedings of Workshop on Traffic Simulation (Bridging Theory and Practice)*, University of Queensland, Brisbane, Australia.
- Eddington, R. (2006). *The Eddington Transport Study: Main Report*. HM Treasury, London, UK.
- FHWA (2006). *Travel Time Reliability: Making It There On Time, All The Time*. FHWA Publication FHWA-HOP-06-070, Washington, DC, USA.
- Gale, C., and Spiers, J. (2001). *Urban Traffic Management and Control Report 4 (Network monitoring, modelling and management): Project summary and evaluation*. MVA Report UTM-04, Dept for Transport, London, UK.
- Hadi, M., Xiao, Y., Wang, T. (2013). Use of the HCM Freeway Facility Analysis and Microscopic Simulation Models as Part of Real-Time Management Decision Support Systems. *Procs of 92nd Transportation Research Board Annual Meeting*, Washington DC, USA, 13-17 Jan 2013.
- Hidas, P. (2001). Simulation modelling for incident management. *Procs of 24th Australasian Transport Research Forum*, Hobart, Australia.
- Kamga, C.N., Mouskos, K.C., Paaswell, R.E. (2011). A methodology to estimate travel time using dynamic traffic assignment (DTA) under incident conditions. *Transportation Research C*, 19: 215–1224.
- Koorey, G., McMillan, S. and Nicholson, A. (2008). *The Effectiveness of Incident Management on Network Reliability: Stage 1*. Research Report 346, NZ Transport Agency, Wellington, NZ.
- Koorey, G., McMillan, S. and Nicholson, A. (2014). *The Effectiveness of Incident Management on Network Reliability: Stage 2*. Research Report, NZ Transport Agency, Wellington, NZ.
- Lowrie, P. (2006). Interfacing microsimulation to intelligent transportation systems. *Procs of NZ Microsimulation Conference*. Queenstown, NZ.
- Luk, J. and Green, D. (2010). *Balancing Traffic Density in a Signalised Network*. Austroads Publication No. AP-R369/10, Austroads Ltd, Sydney, Australia
- Millar, G., Tudge, R., and Wilson C. (2004). Microsimulation evaluation of the benefits of SCATS coordinated traffic control signals. *Proceedings of Transportation Research Board Meeting*, Washington DC, USA.
- Nicholson, A.J., Schmöcker, J.D., Bell, M.G.H. and Iida, Y. (2003). *Assessing Transport Reliability: Malevolence and User Knowledge*. *The Network Reliability of Transport* (Eds. Bell, M.G.H. and Iida, Y.), Elsevier Science: 1-22.
- NZTA (2010). NZ Transport Agency, 2010. *Economic Evaluation Manual*, Volume 1, First Edition, Wellington.

- Payne, H. (1975). Freeway incident detection based upon pattern classification. Proceedings of IEEE Conference on Decision Control including 14th Symposium on Adaptive Processes, Houston, USA: 688–692.
- RTA (2006). SCATS Unusual Congestion Monitor 6.5.1 User Manual, RTA Publication RTATC-335. Roads and Traffic Authority of NSW, Sydney, Australia.
- SACTRA (1999). Transport and the Economy: Full Report. Standing Advisory Committee on Trunk Road Assessment, Department for Transport, London, UK.
- Samant, A., and Adeli, H. (2000). Feature extraction for traffic incident detection using wavelet transform and linear discriminant analysis. *Computer-Aided Civil Infrastructure Engineering*, 15 (4): 241–250.
- Schrank, D., and Lomax, T. (2009). 2009 Urban Mobility Report. Texas Transportation Institute, Texas A&M University, College Station, Texas, USA.
- Srinivasan, D., Jin, X., and Cheu, R.L. (2004). Evaluation of adaptive neural network models for freeway incident detection. *IEEE Transactions on Intelligent Transportation Systems*, 5 (1): 1–11.
- Stazic, B., Taylor, M., and Vogiatzis, N. (2004). Microsimulation at the Transport Systems Centre. Workshop on Traffic Simulation (Bridging Theory and Practice). Brisbane, Australia.
- Transit NZ (2006). Draft Regional CCTV and VMS Strategy. Auckland Traffic Management Unit, Transit NZ, Wellington, NZ.
- USDOT (2000). Incident management successful practices – a cross-cutting study. US Department of Transportation, Washington DC, USA.
- Williams, B., and Guin, A. (2007). Traffic Management Center use of incident detection algorithms: Findings of a nationwide survey. *IEEE Transactions on Intelligent Transportation Systems*, 8 (2): 351–358.
- Yaguang, K., and Anke, X. (2006). Urban traffic incident detection based on fuzzy logic. Proceedings of 32nd Annual Conference of the IEEE Industrial Electronics Society, Paris, France: 772–775.
- Zhang, K., and Taylor, M. (2006). Effective arterial road incident detection: a Bayesian network based algorithm. *Transportation Research C: Emerging Technologies*, 14 (6): 403–417.